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ELECTRO-SEISE, INC.:
AIRBORNE SURVEY

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Abstract

The Rocky Mountain Oilfield Testing Center (RMOTC) has recently completed a test of an airborne micro-gravity and electric field sensing technology developed by Electro-Seise, Inc. of Fort Worth, Texas. The test involved the use of a single engine airplane to gather data over the Teapot Dome oil field along a tight grid spacing and along thirty (30) survey lines. The resultant gravity structure maps, based on the field data, were found to overlay the known structure of Teapot Dome. In addition, fault maps, based on the field data, were consistent with the known fault strike at Teapot Dome. Projected hydrocarbon thickness maps corresponded to some of the known production histories at RMOTC. Exceptions to the hydrocarbon thickness maps were also found to be true.

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Introduction

The Rocky Mountain Oilfield Testing Center (RMOTC) has recently completed a test of an airborne micro-gravity and electric field sensing technology developed by Electro-Seise, Inc. of Fort Worth, Texas. The test involved the use of a single engine airplane to gather data over the Teapot Dome oil field along a tight grid spacing and along thirty (30) survey lines. The Teapot Dome oil field, also known as the Naval Petroleum Reserve No. 3 (NPR-3), is located thirty-five (35) miles north of Casper, Wyoming (See Figure 1). During the testing process, RMOTC witnessed the airborne data gathering capabilities as well as the processing and interpretation of raw data resulting in final contour maps with three dimensional effects.

Background

The use of gravity measurements as an exploration tool in the oil and gas industry dates back many decades. Ander and Chapin[1] present a concise summary of the current gravity methods and uses including advantages and disadvantages. Gravity methods assist the explorationist in identifying the size, shape, and depth of anomalous masses. Ander and Chapin state, "Gravity has advantages over other methods … Fast, inexpensive tool for evaluating large areas.…. Can distinguish sources at exploration depths. Disadvantages of gravity methods include gross imaging of structures, resolution deteriorates with depth and does not provide a structural cross section without additional input. Faults can be identified on gravity maps through steep gradients or truncation of trends."

Recent advances in technology, including the use of high resolution Global Positioning Systems (GPS), have extended the use of gavity techniques to include monitoring of gas cap water movements.[2] The cited paper indicated that with the newer technology, gravity measurements with repeatability as low as 2-3 microgals and elevation changes of less than 1 cm are possible in a field environment.

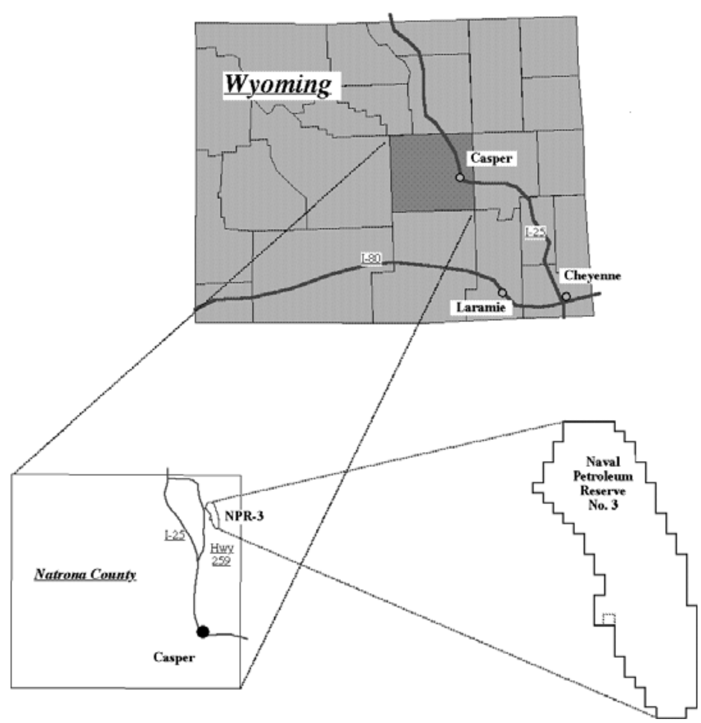


Figure 1. Location of NPR-3

Geologic Setting

The Naval Petroleum Reserve No. 3 (NPR-3) is located in the southwest portion of the Powder River Basin, approximately twenty-seven (27) miles north of Casper, Wyoming. (See Figure 1). NPR-3, often commonly referred to as Teapot Dome, is a large northwest-southeast trending anticline. The anticline is an extension of the larger Salt Creek anticline to the north and is a doubly plunging, asymmetrical anticline. The structure drops much more rapidly on the west flank than on the east side of the structure. See Figure 6 for an illustrative structure map based on the lowest producing formation found at NPR-3.

Production from Teapot Dome commenced in the 1920’s with full development activities beginning in 1976 after the effects of the first Arab oil embargo. Production has been from nine (9) productive horizons with the Shannon, Steele and Niobrara Shales, Second Wall Creek, and Tensleep Formations being the most productive. Figure 2 below illustrates the stratigraphy present at Teapot Dome.

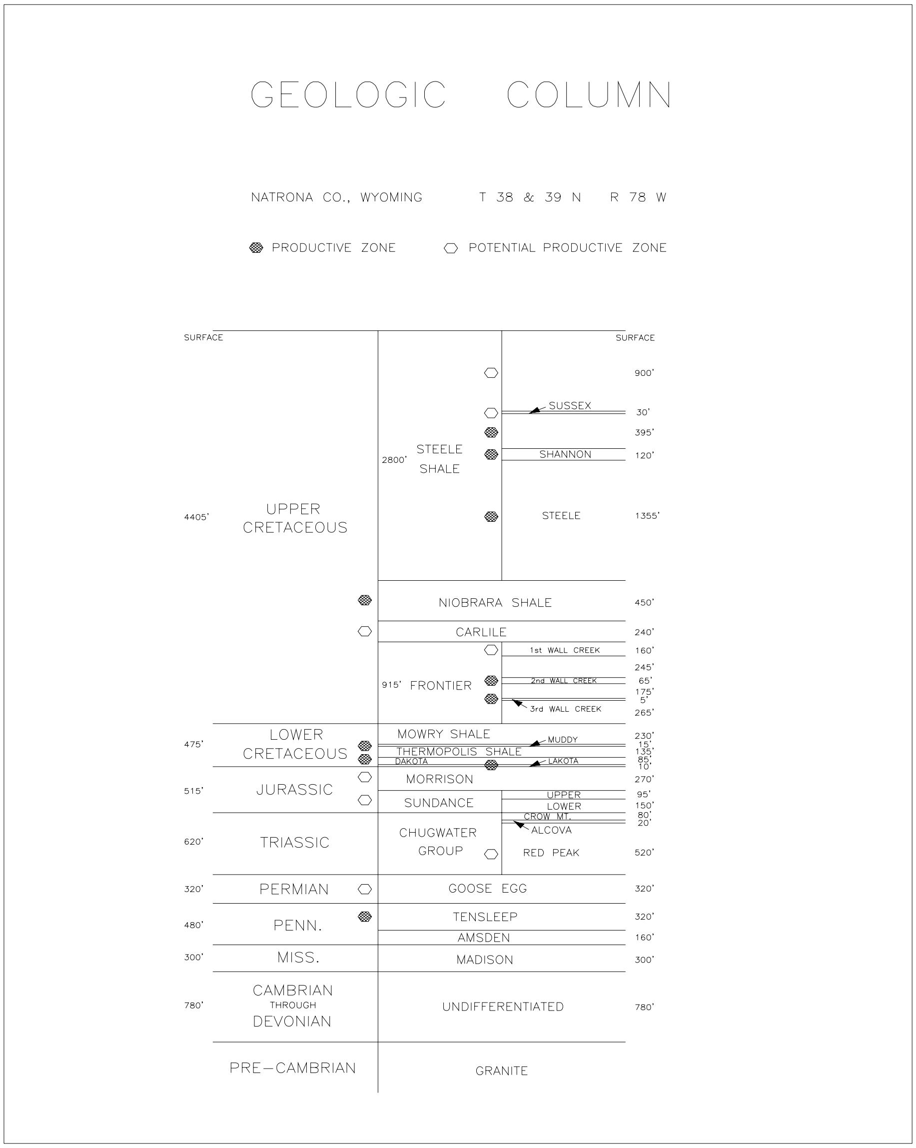


Figure 2. Geologic Column of Teapot Dome Field

Table 1. Brief Geologic Description of Horizons at NPR-3	
Formation: Basement	**Formation:** Flathead ss
Age: Precambrian	**Age:** Cambrian
Lithology: Complex of metamorphic and intrusive rocks.	**Lithology:** Transgressive marine sandstone
Production: None	**Production:** None
Formation: Madison	**Formation:** Amsden
Age: Mississippian	**Age:** Pennsylvanian
Lithology: Marine limestone	**Lithology:** Interbedded marine limestone, dolomite, sandstone, shale, chert
Production: High quality hot water	**Production:** None
Formation: Tensleep ss	**Formation:** Goose Egg
Age: Penns/Permian	**Age:** Permian
Lithology: Interbedded dune sands and interdune dolomites/evaporites	**Lithology:** Marine and nonmarine limestones, dolomites, evaporites, shales, and siltstones.
Production: Sour oil	**Production:** None
Formation: Chugwater (includes Red Peak, Alcova ls, and Crow Mountain members)	**Formation:** Sundance
Age: Triassic	**Age:** Upper Jurassic
Lithology: Oxblood red marine and nonmarine sands, shales, limestones, gypsum, evaporites.	**Lithology:** Glauconitic shallow marine sandstone and shales.
Production: None	**Production:** None
Formation: Morrison	**Formation:** Lakota
Age: Upper Jurassic	**Age:** Lower Cretaceous
Lithology: Fluvial sandstones and shales	**Lithology:** Fluvial conglomeritic sandstones.
Production: None	**Production:** Oil
Formation: Thermopolis Shale	**Formation:** Mowry Shale
Age: Lower Cretaceous	**Age:** Lower Cretaceous
Lithology: Marine shale, including the nonmarine Muddy and Dakota sandstones	**Lithology:** Marine siliceous shale.
Production: Oil	**Production:** Oil
Formation: Frontier	**Formation:** Carlisle Shale
Age: Upper Cretaceous	**Age:** Upper Cretaceous
Lithology: Marine sandstones and shale. Includes the 1st, 2nd, and 3rd Wall Creek Sandstone members.	**Lithology:** Marine shale.
Production: Oil and gas (2nd and 3rd WC)	**Production:** None
Formation: Niobrara Shale	**Formation:** Steele Shale
Age: Upper Cretaceous	**Age:** Upper Cretaceous
Lithology: Marine shale.	**Lithology:** Marine shale with offshore bar sandstones (Shannon Member)
Production: Oil (from fractures)	**Production:** Oil from Shannon ss and underlying fractured shale.
Formation: Mesa Verde ss (outcrop)	
Age: Upper Cretaceous	
Lithology: Marine and nonmarine sandstones, shales, carbonaceous shales.	
Production: None	

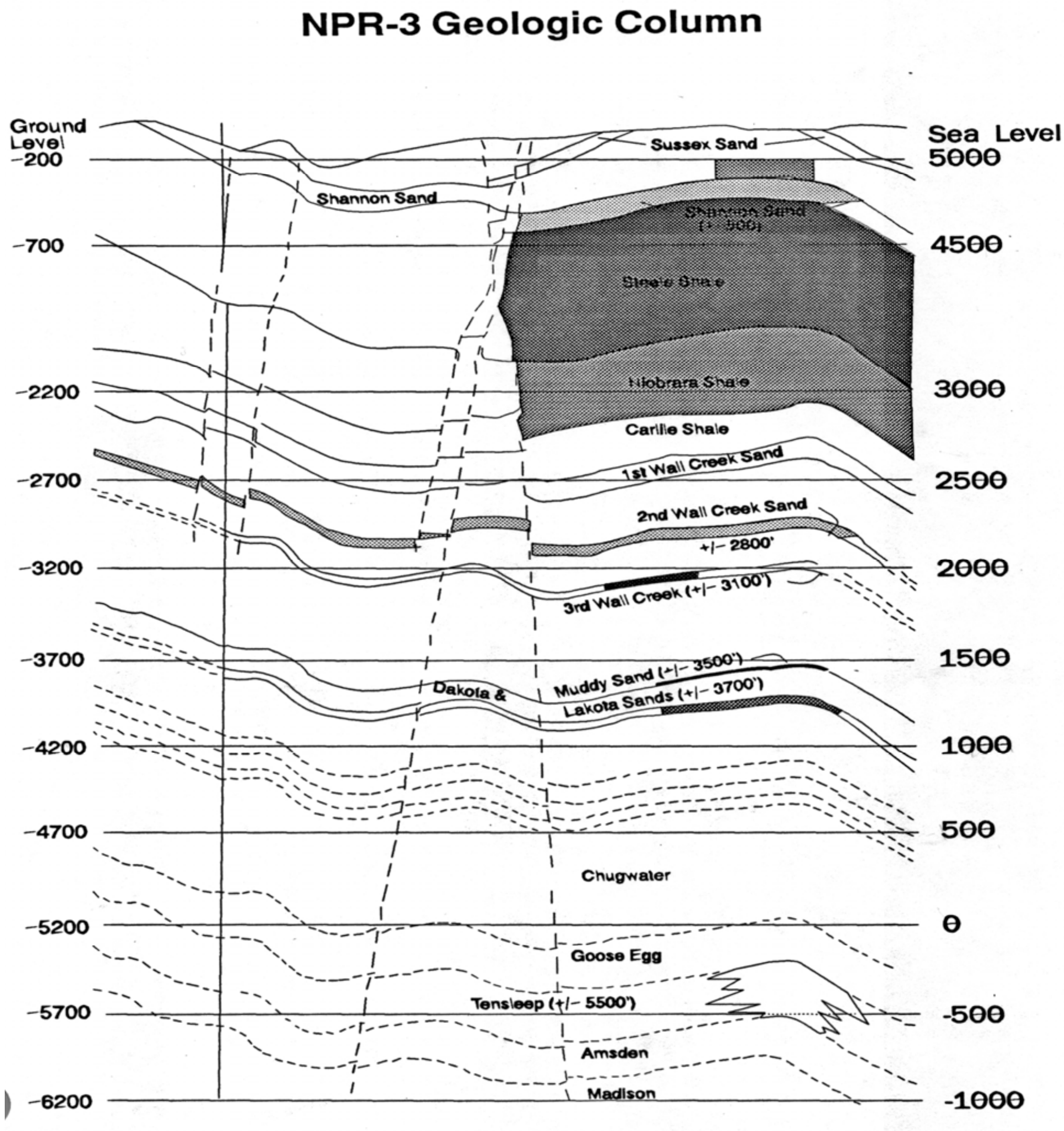


Figure 3. NPR-3 Conceptual Cross Section

Structural Setting

Figure 3 is a conceptual cross section of Teapot Dome. The top of the Shannon Sandstone lies approximately 250 feet below the surface at the top of the anticline. At the edge of the field, the Shannon top is approximately 1000 feet below the surface. From a gravity survey viewpoint, the basement rock, referred to as granite, will be approximately 750 feet closer to the surface at the top of the anticline than at the edges.

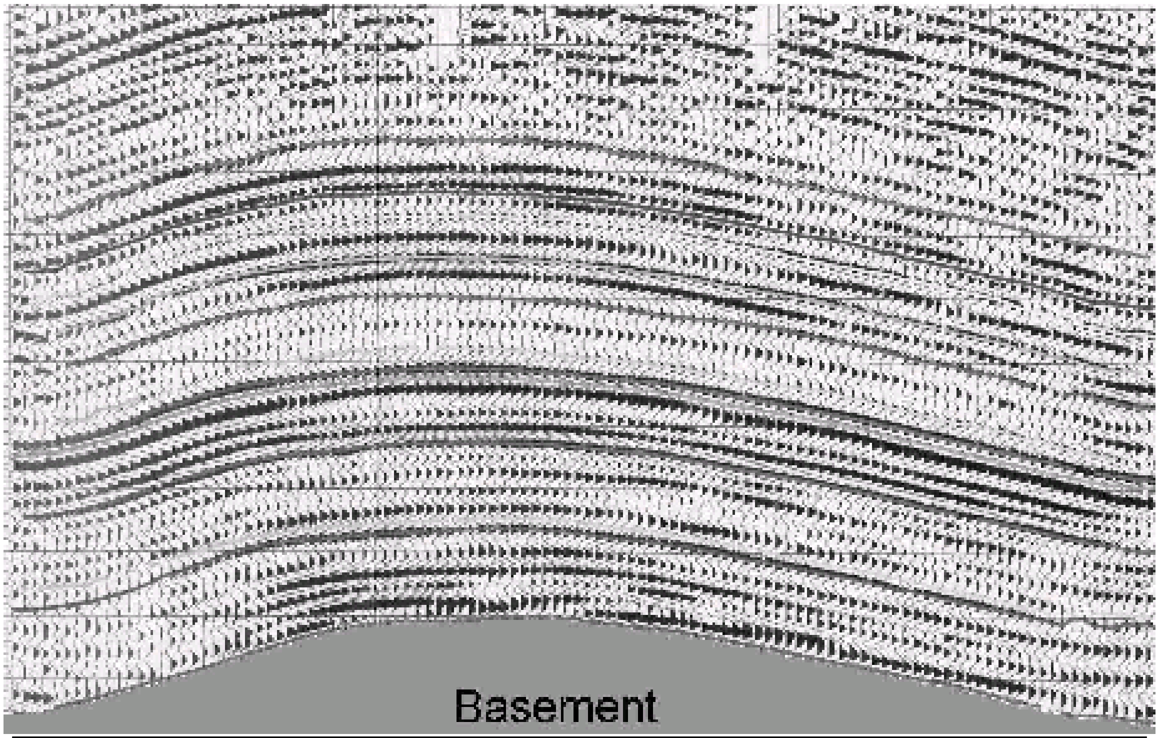


Figure 4. Reprocessed 2D Seismic Data with Basement Rock

The density contrasts in the overlying formations are essentially the intrusion of the higher density granite basement rock as compared to the marine shales and sandstones of the producing formations Figure 4 is an older seismic line that has been recently reprocessed. The intrusion of the basement rock is shown graphically with editing of the image. Table 1 lists some average porosities and reservoir properties for the sandstone producing formations at NPR-3.

Assuming average rock properties for each formation, the bulk densities are calculated and shown in Table 2.

Table 2. Average Reservoir Properties at NPR-3

	Shannon	2nd Wall Creek	Muddy	Tensleep
Porosity	18	15	13	8
Permeability	63	100	300	80
Depth	250	2900	3600	5500
Net Thickness	65	30	5	50
Cum Oil Produced, mmbbl 1996	10.1	10.0	.74	1.46
Bulk Density g/cc calculated	2.35	2.40	2.43	2.52

The bulk density of the two (2) fractured shale formations, Steele and Niobrara Shale are not calculated due to lack of matrix porosity data but can be estimated from the bulk density log readings. The Steele Shale bulk density reading is estimated at 2.45 grams per cubic centimeter. The bulk density for the Niobrara Shale is estimated to be similar. The density of the basement, referred to as granite, is believed to be in the 2.65–3.0 range with no primary porosity. In the early 1950's, some limited footage was cored in the basement rock but an analysis was never performed on the granite samples.

Data Gathering

RMOTC witnessed the initial data gathering operations aboard the single engine airplane. The first of six (6) survey lines were recorded at night to reduce interference. The data gathering aboard the aircraft involved a proprietary sensor developed by Electro-Seise, Inc. using a Differential Global Positioning System (DGPS) and a laptop computer interfaced with a data recording module. Using minimal information from RMOTC, Electro-Seise designed a grid of thirty (30) survey lines spaced 200 meters apart. The survey grid is shown in Figure 5.

Electro-Seise, prior to the data gathering flight, had programmed the start and stop positions of each of the survey line into the computer. As the airplane would approach the start position of the survey line, the laptop and data gathering module would begin collecting data when the start point was reached. The plane would then follow the prescribed route using a differential GPS system with indicator lights to maintain the plane on an exact course. If the plane veered off course, the pilot would reset the equipment and start the entire line again. The GPS readings in the cockpit matched the GPS readings being recorded on the laptop due to the interface between the systems.

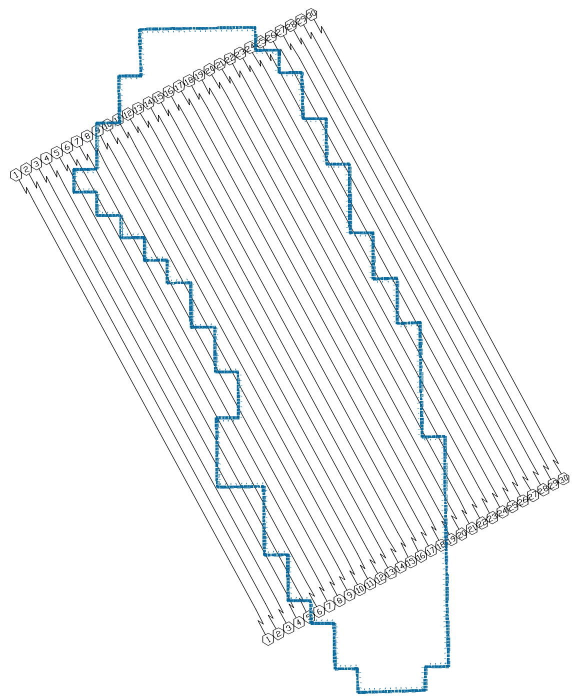


Figure 5. Electro-Seise Airborne Survey Grid

Each survey line was repeated twice. The two-line profile captures the exact same sample data point in a northerly direction as well as a southerly direction. Electro-Seise states that by using this method “no correction is needed to manipulate the data, such as the Bouguer Algorithms, for correction in the vertical component of mass distortions.”

Recent improvements in GPS systems and the abandonment of signal degradation by the U.S. Government allows position determination to less than a meter (Oil and Gas Journal Feb 26, 2001 p. 17).

RMOTC witnessed the raw data graphically displayed at the end of each initial survey line, however, did not inspect the proprietary sensor or its design. Electro-Seise, Inc. (ESI) literature states, “ESI exploits an old theory and instrumentation about the Earth’s forces as measured by using a passive sensor in an aircraft and combining the signal with earth’s fair weather electric field.” The Electro-Seise method incorporates the Earth’s electrical field data into the horizontal gradient of the gravitational field data.

Review of Data

After the raw data was collected over the thirty (30) survey lines, Electro-Seise personnel spent several weeks at RMOTC processing the raw data including the necessary corrections. One such correction, cited by Ander and Chapin, is the EÖTVÖS correction necessary for gravity collected on moving platforms. The correction is for the platform’s velocity and heading – data easily obtained through the GPS system and instrumentation. From the processed data numerous maps were generated by Electro-Seise, including maps with three-dimensional aspects. The three-dimensional presentation was possible with use of special plotting routines and the use of Chromatek Inc. glasses.

Exploration Tool vs. Field Development Tool

The produced maps would generally be used in an exploration environment to identify possible structures or anomalous masses such as ore bodies or salt deposits. The use of the maps in a producing field environment, such as Teapot Dome with over a thousand wells drilled, is not the usual application of this technology. The objective of this report is to show the overall correspondence between the Electro-Seise data as processed and interpreted by Electro-Seise, and the known geologic structure of Teapot Dome.

The known geologic structure of Teapot Dome is a function of depth and producing formation. The shallow Shannon formation has been extensively drilled in the southern half of the field. In the northern half, north of a major fault in sections 27 and 35, the Shannon is non-productive. In addition, the western and southern flank of the anticline is also not productive so well control is also sparser in those areas. In general, the deeper the producing horizon, the less well control is possible. For example, the deepest producing formation at RMOTC is the Tensleep sand at approximately 5500 feet below the surface. The Tensleep has been penetrated twenty-eight (28) times resulting in approximately a dozen commercial wells. The Shannon, however, has had over five hundred (500) wells produced with the majority being economic due to its shallow depth.

The use of an exploration tool on a developed field makes some comparisons difficult. It is the intent of this report to show the similarities and differences of the exploration data and field data. Due to the lower well spacing in the deeper formations, it is not always possible for a one-to-one comparison since log or core data doesn't exist. Recent 3D Seismic data (January, 2001) may provide additional insight and comparisons after the data is processed and interpreted in the coming months.

Maps Generated

Based on the interpreted and contoured data, a series of maps were generated for RMOTC. Electro-Seise worked in an AutoCad format with multiple layers and images on each map. Base maps of wells were provided by RMOTC along with scanned images of older reservoir maps. Electro-Seise Technicians handled the overlay of new and old maps producing a series of new maps for review and analysis.

Table 3. List of Maps Produced for NPR-3

Title of Map	Formation	Features
ESI Faults and Hand Contours RMOTC Seismic Thrust Faults	Tensleep	ESI Structure overlay with 1985 structure map
ESI Faults and Hand Contours RMOTC Seismic Thrust Faults	Tensleep	Similar to above without 1985 structure map
ESI Faults and Hydrocarbon Thickness	Tensleep	Hydrocarbon Potential with structure
ESI Faults and Hydrocarbon Thickness	Tensleep	Similar to above without structure
RMOTC Tensleep Structure Geophysical Time Structure Map	Tensleep	Re-interpretation of 2D seismic lines on structure
RMOTC Tensleep Structure Geophysical Time Structure Map	Tensleep	Similar to above without structure
ESI 2nd Wall Creek Structure Hand Contoured	Second Wall Creek	ESI structure overlay with RMOTC structure
ESI 2nd Wall Creek Structure Hand Contoured	Second Wall Creek	Similar to above without RMOTC structure
ESI 3D Hydrocarbon Thickness RMOTC Structure	Second Wall Creek	Hydrocarbon Potential with RMOTC structure
ESI 3D Hydrocarbon Thickness	Second Wall Creek	Similar to above without structure
ESI Shannon Structure	Upper Shannon	ESI structure overlay with RMOTC structure
ESI Shannon Level 1RMOTC Upper Shannon	Upper Shannon	Hydrocarbon Thickness with RMOTC structure
ESI Shannon Level 2 RMOTC Upper Shannon	Upper Shannon	Similar to above at slightly lower level

The following is an analysis of the maps as presented by Electro-Seise. The focus of the analysis is primarily on the structure maps produced by Electro-Seise. For presentation purposes of this report, the maps were modified slightly to produce presentation quality graphics on a small-scale format. The contour lines were closed and other minor changes made. In general, RMOTC separated the individual contour levels for each horizon as presented by Electro-Seise. Simplified versions of the structure maps were also developed by hand drawn overlays in AutoCad. The isolation of the individual closed contours and the overlay of the structure maps are shown in the following sections for each horizon mapped by Electro-Seise.

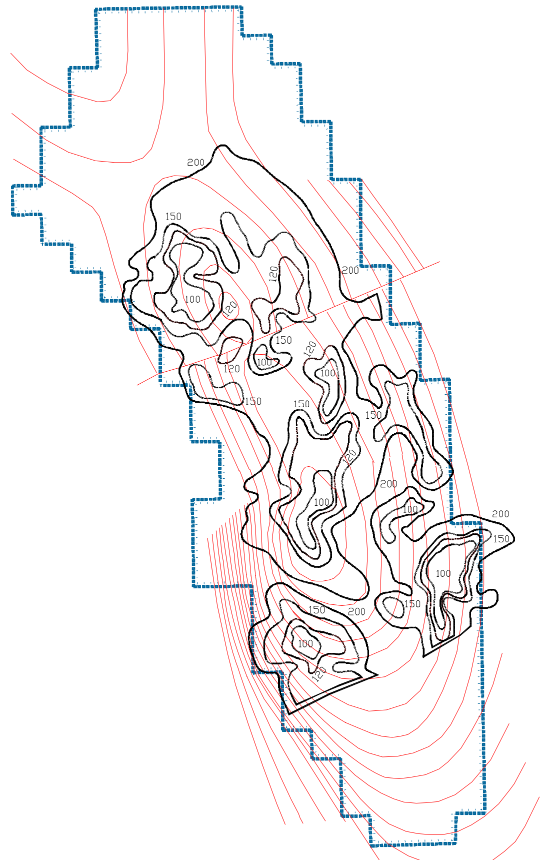


Figure 6. Tensleep Horizon shown with all contour levels.

Figure 6 shows the Electro-Seise contours for the Tensleep horizon. The Tensleep is the deepest oil producing reservoir at Teapot Dome with the sands at approximately 5400 feet below ground level. The Tensleep is approximately 1500 feet above the basement intrusive rock.

The contour values presented by Electro-Seise are negative. The negative contour values that are shown are -100, -120, -150, and -200. RMOTC separated the above map into individual contour levels to illustrate the overlay on structure of the individual values. Figures 7-10 illustrate this analysis and the corresponding graphical comparison. The values are derived from the micro-gravity measurements taken from the airborne surveys. Since the values are believed to be relative, absolute units are not given.

The structure map shown is a hand drawn Autocad overly of a RMOTC scanned structure map. The map was simplified for presentation purposes by removing the minor faults shown on the original map. Recent 3D Seismic data (January, 2001) may change the above map slightly.

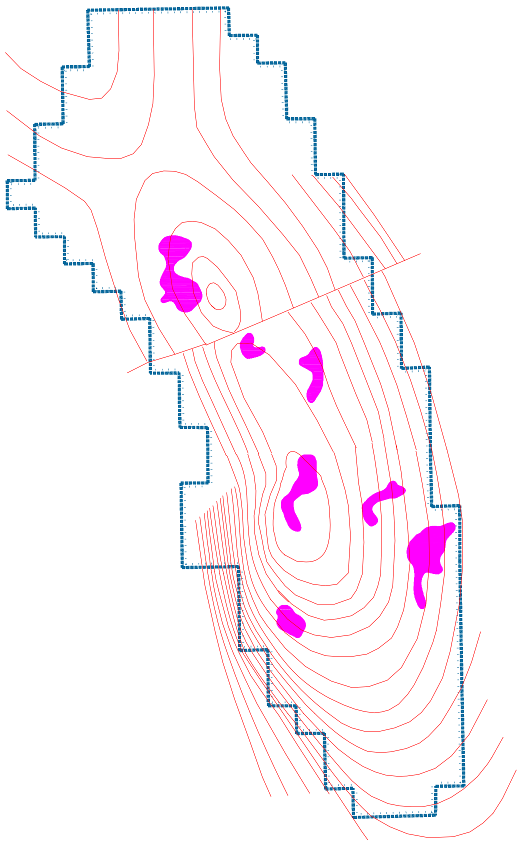


Figure 7. Tensleep Horizon shown with the -100 contour level.

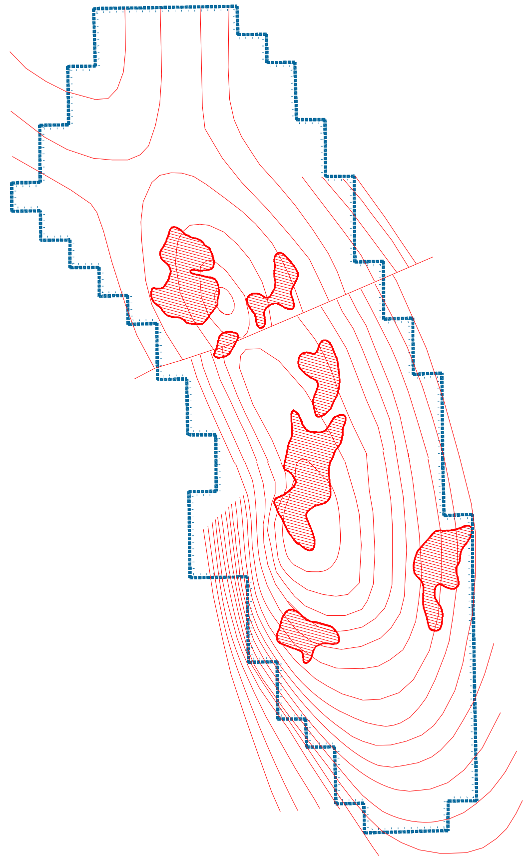


Figure 8. Tensleep Horizon shown with isolated contour level of - 120.

The contour (-100) is shown in Figure 7. Four (4) of the closed contours are close to, or on, the anticlinal axis. From an exploration viewpoint, the contours would indicate the possibility of an underlying structure in a northwest by southeast trending direction. The other three (3) local highs are in the southern portion of the anticline. The southern three (3) local highs are on the nose of the anticline and have not been previously mapped. The placement of the highs in the southern portion has resulted in steep micro-gravity gradients. Ander and Chapin[1] state, " Faults can be identified through either steep gradients or truncation of trends."

The contour (-120) is shown in Figure 8. Similar to the closed contour level of –100, four (4) of the closed contours are close to, or on, the anticlinal axis. The closed contour level of –120 is fairly close to the closed contour level of –100 and similar conclusions could be made about the possible presence of an underlying structure. At this contour level there are two (2) local highs in the southern portion of the anticline. The southern two (2) local highs are on the nose of the anticline and have not been previously mapped.

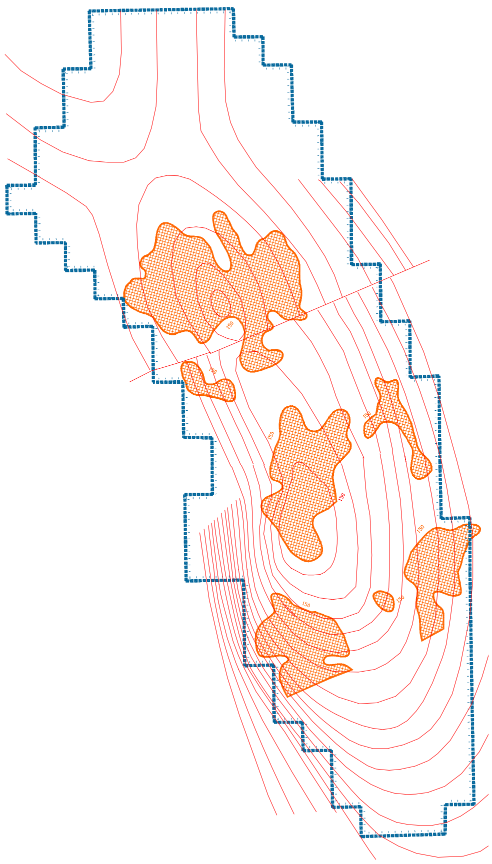


Figure 9. Tensleep Horizon shown with isolated contour level of - 150.

The contour (-150) is shown in Figure 9. The closed contour level continues to expand. Two (2) nodes cover the top of the anticline with smaller nodes developing along the flanks of the anticline. The two (2) nodes along the southern portion of the anticline also continue to expand with a smaller node developing. The close spacing of the three (3) contour levels (-100, -120, and -150) result in steep gradients which indicate possible faulting. The presence of minor and major faulting at Teapot Dome is well documented and exists on every major horizon. Fault displacement can range from just a few feet to over 100 feet depending upon the reservoir depth and location.

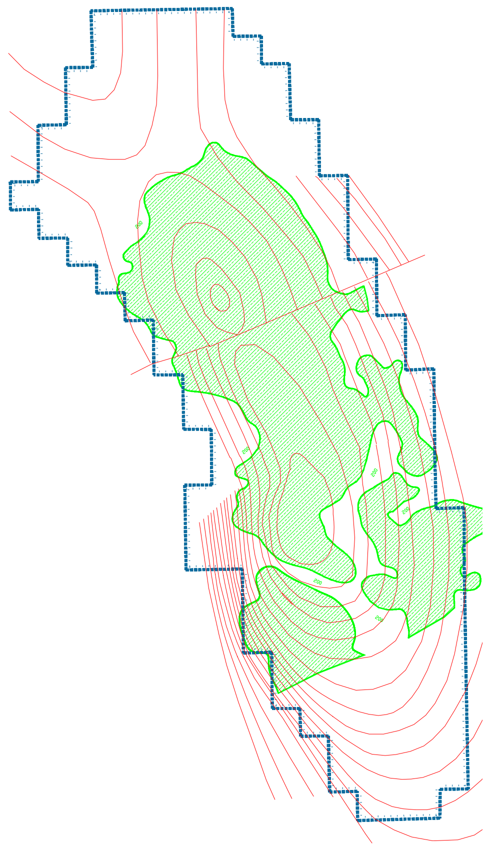


Figure 10. Tensleep Horizon shown with isolated contour level of - 200.

The contour (-200) is shown in Figure 10. The -200 closed contour level is the last level mapped by Electro-Seise for the Tensleep horizon. At this level, the two (2) nodes on top of the anticline have merged with a single node covering the top of the structure and draping over the eastern and western flanks. The two (2) southern nodes continue to remain separate possibly due to a projected fault. See Figure 10. From an exploration viewpoint, the top of the structure is not as well identified as previous contour levels indicated. The northwest-southeast trending nature of the structure is still evident.

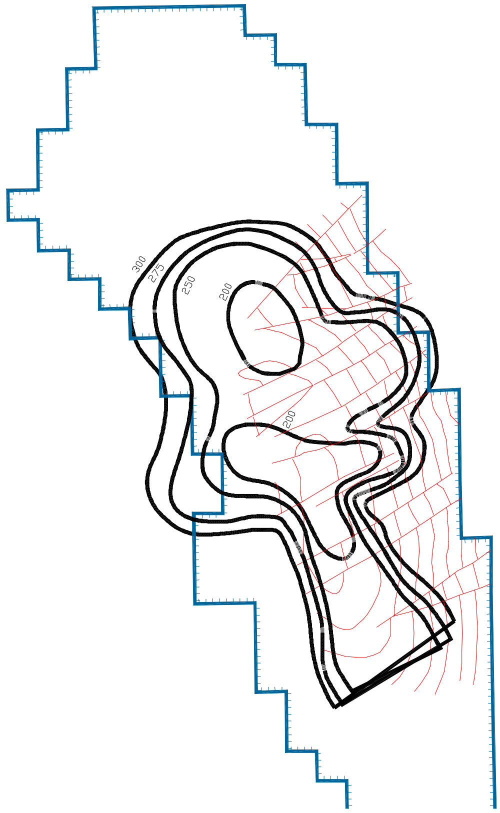


Figure 11. Shannon Horizon shown with all contour levels.

Figure 11 shows the Electro-Seise contours for the Shannon horizon. The Shannon is the shallowest oil-producing reservoir at Teapot Dome, with the sands at approximately 250 feet below surface at the top of the anticline. Along the eastern flank, Shannon is approximately 1000 feet deep and is approximately 6600 feet above the basement intrusive rock.

The contour values presented by Electro-Seise are negative. The negative contour values that are shown are -200, -250, -275, and -300. RMOTC separated the above map into individual contour levels to illustrate the overlay on structure of the individual values. Figures 12-15 illustrate this analysis and the corresponding graphical comparison. The values are derived from the gravity measurements taken from the airborne surveys. Since the values are believed to be relative, absolute units are not given.

The structure map shown is a hand drawn Autocad overlay of a RMOTC scanned structure map. The original structure map was based on existing productive acreage. The map was not constructed for areas of the field where the Shannon is not productive. Many of the minor faults within the Shannon were retained to show the relative frequency of faulting and the general fault direction. The recent 3D Seismic data (January, 2001) will not change the interpretation of the Shannon because at this shallow depth seismic data was not possible.

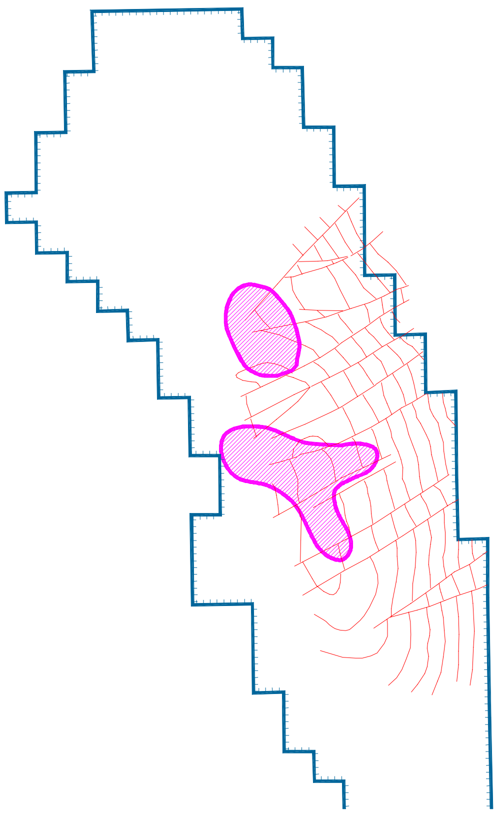


Figure 12. Shannon Horizon shown with the -200 contour level.

The contour level (-200) is shown in Figure 12. The two (2) closed contour levels essentially straddle the top of the anticline shown at the Shannon horizon. The two (2) closed contours are close to or on the anticlinal axis. The southern closed contour does drape over the western flank. From an exploration viewpoint, the contours would indicate the possibility of an underlying structure in a northwest by southeast trending direction. The top of the structure would be isolated to a small portion of the field based on this contour level.

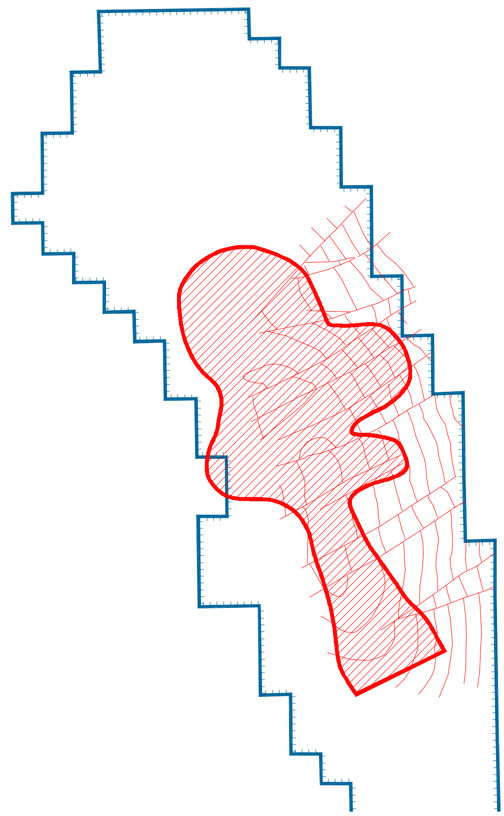


Figure 13. Shannon Horizon shown with the -250 contour level.

The contour level (-250) is shown in Figure 13. The two (2) closed contour levels have merged into a single node. This closed contour essentially straddles the top of the anticline and drapes over the western and eastern flanks. The contour has also extended down the southern nose of the anticline. From an exploration viewpoint, the contour would indicate the possibility of an underlying structure in a northwest by southeast trending direction. The top of the structure would be coincidental with the major axis of the hatched area.

Figure 14. Shannon Horizon shown with the -275 contour level.

The contour level (-275) is shown in Figure 14. This separate contour is very similar to the previous due to the close spacing of the lines. From an exploration viewpoint, the contour would indicate the possibility of an underlying structure in a northwest by southeast trending direction. The top of the structure would be coincidental with the major axis of the hatched area.

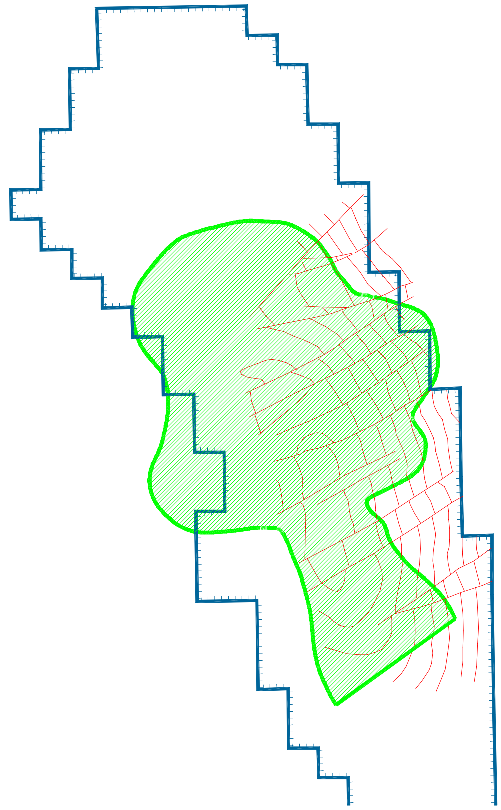


Figure 15. Shannon Horizon shown with the -300 contour level.

The contour level (-300) is shown in Figure 15. The –300 closed contour level is the last level mapped by Electro-Seise for the Shannon horizon. At this level, a single node covers the top of the structure and drapes over the eastern and western flanks. From an exploration viewpoint, the top of the structure is not as well identified as the –200 level contour indicated. The axis of the structure would be coincidental with the major axis of the hatched area.

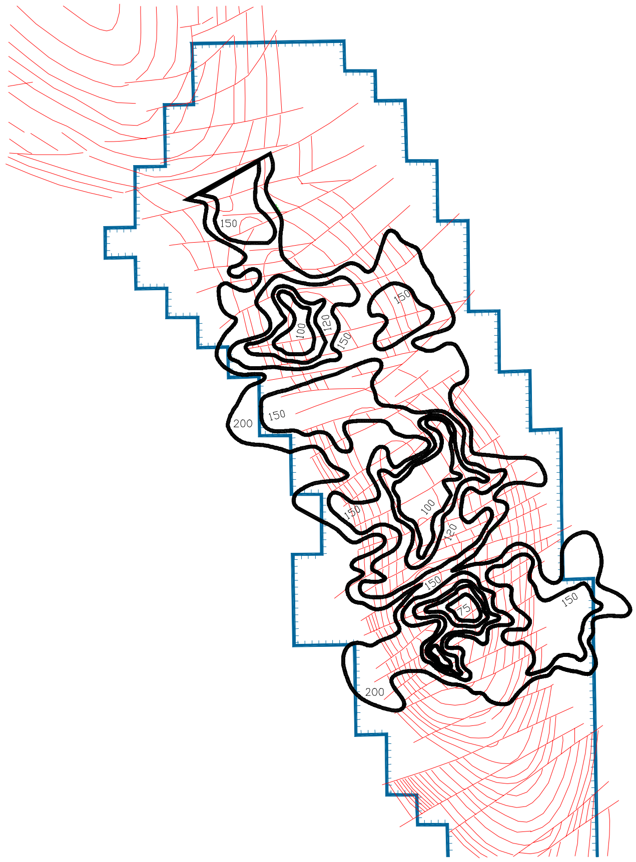


Figure 16. Second Wall Creek Horizon shown with all contour levels.

Figure 16 shows the Electro-Seise contours for the Second Wall Creek Horizon. It is essentially at mid-depth of the producing reservoirs at approximately 2800 feet below surface, and is approximately 4000 feet above the basement intrusive rock.

The contour values presented by Electro-Seise are negative. The negative contour values that are shown are -75, -100, -120, -150, and -200. RMOTC separated the above map into individual contour levels to illustrate the overlay on structure of the individual values. Figures 17 to 21 illustrate this analysis and the corresponding graphical comparison. The values are derived from the gravity measurements taken from the airborne surveys. Since the values are believed to be relative, absolute units are not given.

The structure map shown is a hand drawn Autocad overly of a RMOTC scanned structure map. The original structure map extended off the field, north towards the larger Salt Creek Anticline. The projected faults of the Second Wall Creek were retained to show the relative frequency of faulting and the general fault direction. The recent 3D Seismic data (January, 2001) may change the structure map slightly when mapping is complete.

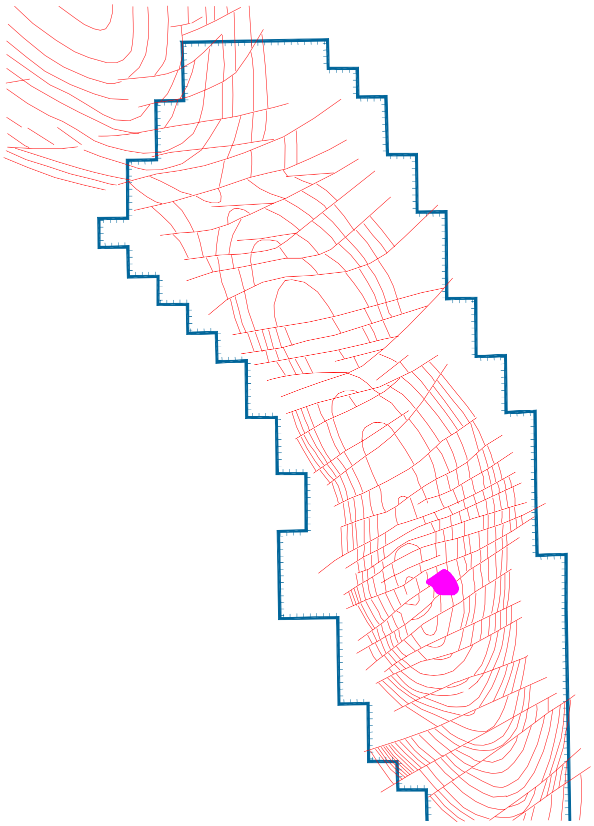


Figure 17. Second Wall Creek Horizon shown with the -75 contour level.

The contour level (-75) is shown in Figure 17. The single closed contour is very close to the structural top in the southern portion of the field. From an exploration viewpoint, the closed contour would indicate near top of an underlying structure. Based on this high contour level, the areal extent of the structure would not be delineated.

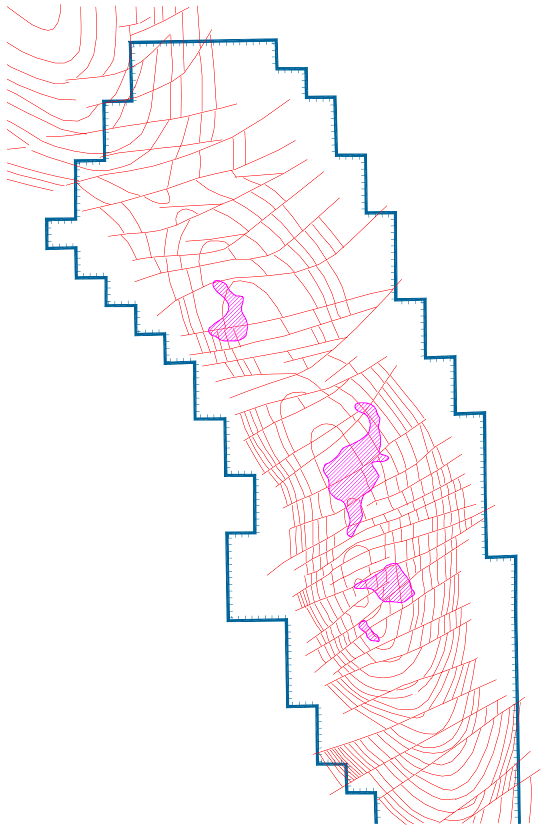
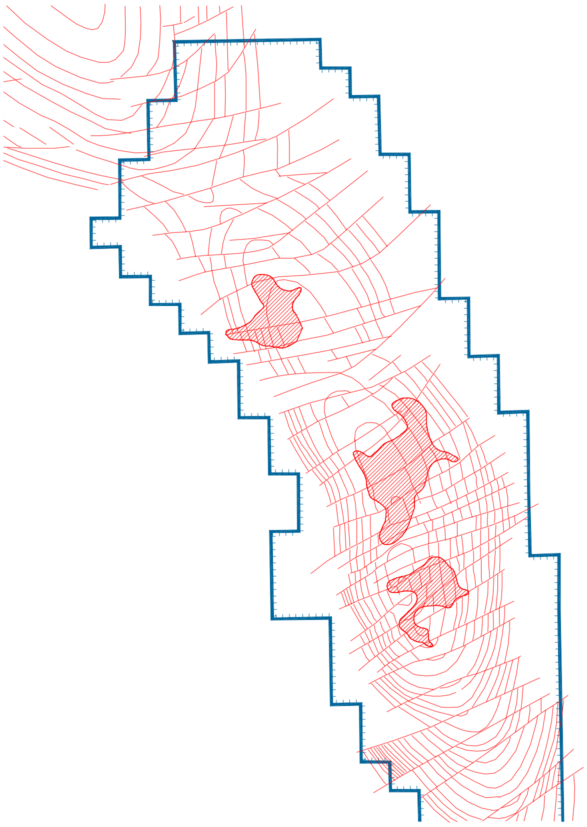


Figure 18. Second Wall Creek Horizon shown with the -100 contour level.

The contour level (-100) is shown in Figure 18. The closed contour levels essentially straddle the axis of the anticline shown at the Second Wall Creek Horizon. The closed contours give a better indication of the areal extent of the anticline than the previous (-75) contour level. From an exploration viewpoint, the above contours present one of the best correlations seen with Electro-Seise data. The top of the structure is clearly identified both in the Northern Second Wall Creek and the Southern Second Wall Creek.



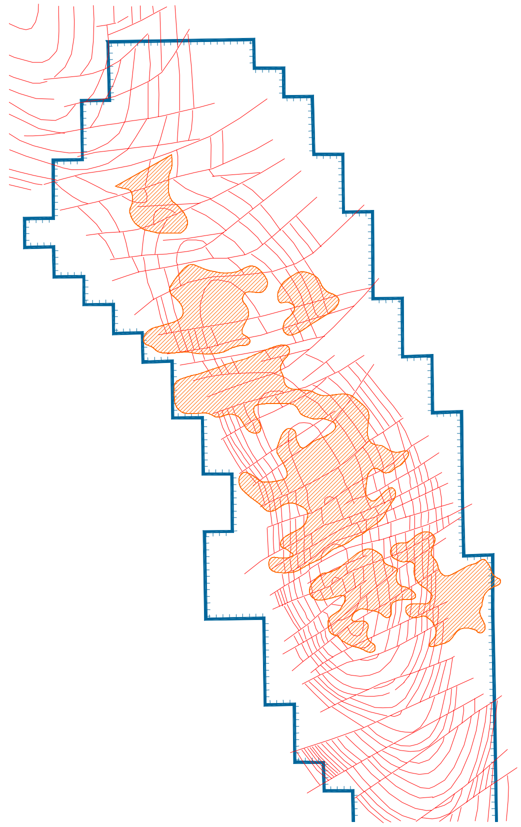


Figure 19. Second Wall Creek Horizon shown with the -120 contour level.

The contour level (-120) is shown in Figure 19. The closed contour levels essentially straddle the axis of the anticline shown at the SWC Second Wall Creek Horizon. The two (2) southern nodes at the previous contour level (-100) have merged into a single node. Once again, a very good correlation is seen with Electro-Seise data and structure. The top of the structure is clearly identified both in the Northern Second Wall Creek and the Southern Second Wall Creek.

Figure 20. Second Wall Creek Horizon shown with the -150 contour level.

The contour level (-150) is shown in Figure 20. The closed contours have expanded over the eastern and western flanks. Several new nodes have appeared. From an exploration viewpoint, the top of the structure is not as well identified as the -120 level contour indicated. The contours would indicate the possibility of an underlying structure in a northwest by southeast trending direction.

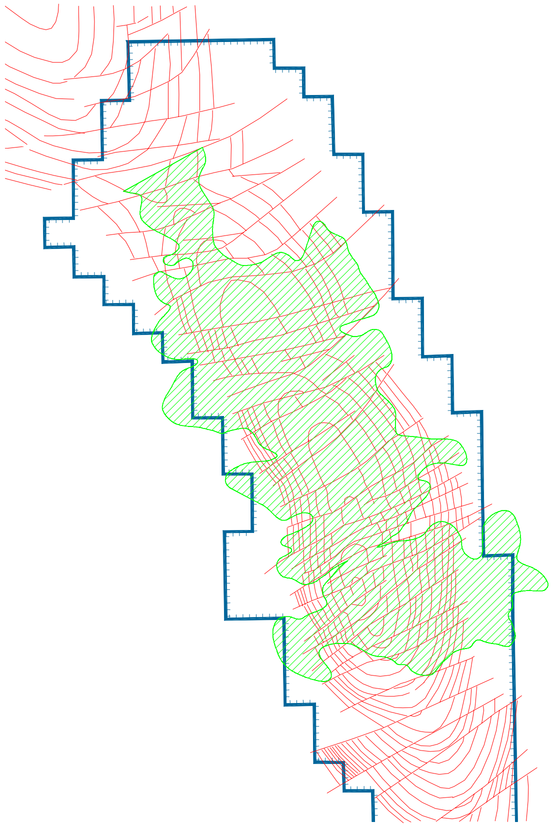


Figure 21. Second Wall Creek Horizon shown with the -120 contour level.

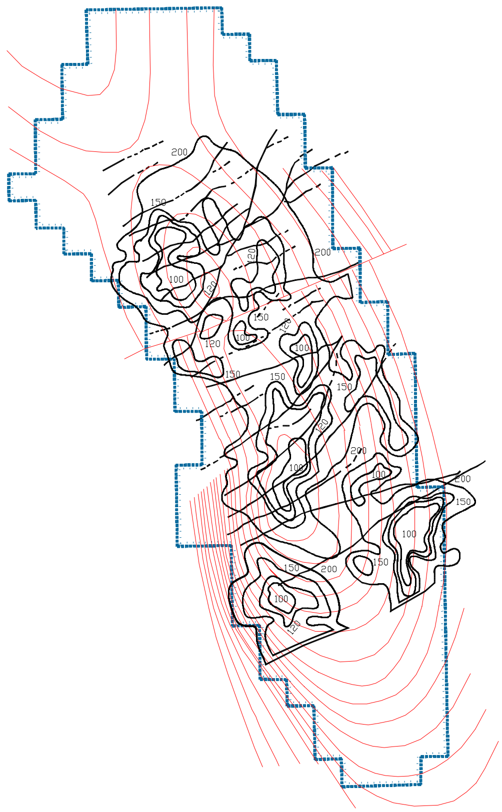


Figure 22. Faults shown on the Tensleep Structure.

The contour level (-200) is shown in Figure 21. The individual nodes have merged into a single large area. This area or node covers the top of the anticline and the eastern and western flanks. The contours would indicate the possibility of an underlying structure in a northwest by southeast trending direction. The axis of the structure would be coincidental with the major axis of the hatched area.

Fault Interpretation

Electro-Seise has presented RMOTC with a new fault interpretation of the structure based primarily on their data. (See Figure 22). The presence of minor and major faulting at Teapot Dome is well documented and exists on every major horizon. Fault displacement can range from just a few feet to over 100 feet depending upon the reservoir depth. As previously reported, Ander and Chapin[1] state, “Faults can be identified through either steep gradients or truncation of trends”.

The exact combination of data utilized by Electro-Seise in constructing their interpretation of the faulting at Teapot Dome is not known, however, the interpretation seems to be consistent with the industry use of steep gradients and truncation of trends. In particular, the southern most fault presented by Electro-Seise is begins at a steep gradient node and parallels another steep gradient to the west.

Fault maps, as presented by Electro-Seise, were generally consistent with the known fault direction at Teapot Dome. This alternate fault interpretation may indicate specific areas of focus for recent 3D Seismic data (January 2001).

Hydrocarbon Thickness Maps

Electro-Seise generated a series of hydrocarbon thickness maps for RMOTC. The maps were generated for the three (3) major horizons of interest, Shannon, Second Wall Creek, and the Tensleep. The calculation of the hydrocarbon thickness is believed to be a combination of their field electric readings and gravimetric readings.

Tensleep production has been limited to a small area at the crest of the structure in section 10. Exploratory wells outside of this area have not been commercially productive. The wells have either produced minor amounts of oil with large amounts of water or essentially all water. The Tensleep is a strong water drive reservoir with regeneration from the Big Horn Mountains.

Table 4. Tensleep Cumulative Production

Well	Cum oil, mBO	Cum Water, mBW	Color Contour
56-TPX-10	349.1	23,600	yellow
54-TPX-10	291.3	16,900	orange
62-TPX-10	228.3	15,700	green
44-1-TPX-10	208.4	15,200	orange
74-TPX-10	174.6	Unknown	green
55-TPX-10	127.1	11,600	orange
63-TPX-10	91.0	11,100	green
73-TPX-10	57.0	5,600	yellow
76-TPX-10	51.7	8,200	green
43-TPX-10	73.4	8,000	green
75-TPX-10	19.9	4,700	green
72-TPX-10	14.6	1,600	orange
43-2-TPX-10	7.0	1,000	yellow

Table 4 lists the cumulative oil and water production for wells in section 10 with significant oil production. The individual well performance in the Tensleep is quite varied. Structure seems to be a primary factor with oil production along with the timeframe when the well was drilled. Faults are also believed to influence the individual well performance in addition to the stratigraphy. The complicated interrelationships have made it difficult to predict the performance of new wells and the optimum drilling locations.

In general, the wells with significant oil production fall within the medium to high hydrocarbon thickness. From Figure 24 and Table 4, Wells 54-TPX-10, 44-1-TPX-10, and 55-TPX-10 have high hydrocarbon thickness (orange) and high cumulative oil production. All three wells are within a high projected hydrocarbon area. This particular correlation is perhaps the most definitive match among all the different horizons. Wells 76-TPX-10, 43-TPX-10, and 75-TPX-10 generally had lower hydrocarbon thickness and lower cumulative production. Exceptions to the overall correlation include 62-TPX-10 with a high cumulative production and a lower hydrocarbon thickness. Conversely, well 72-TPX-10 had a high hydrocarbon thickness (orange) and low cumulative production.

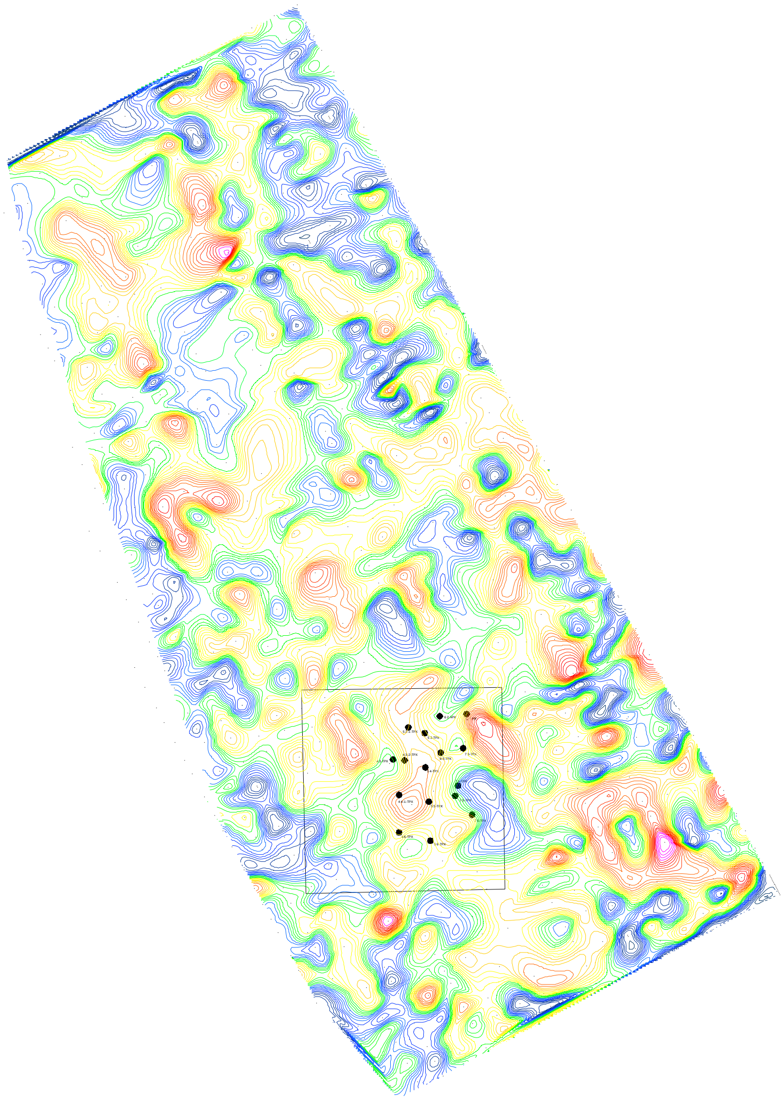


Figure 23 Electro-Seise Hydrocarbon Thickness for Entire Field

Figure 24 shows section 10 along with the projected hydrocarbon thickness color coded map. The blue contours are the lower hydrocarbon thickness; green, yellow and light orange are the medium hydrocarbon thickness, and dark orange, red, and magenta are the highest hydrocarbon thickness.

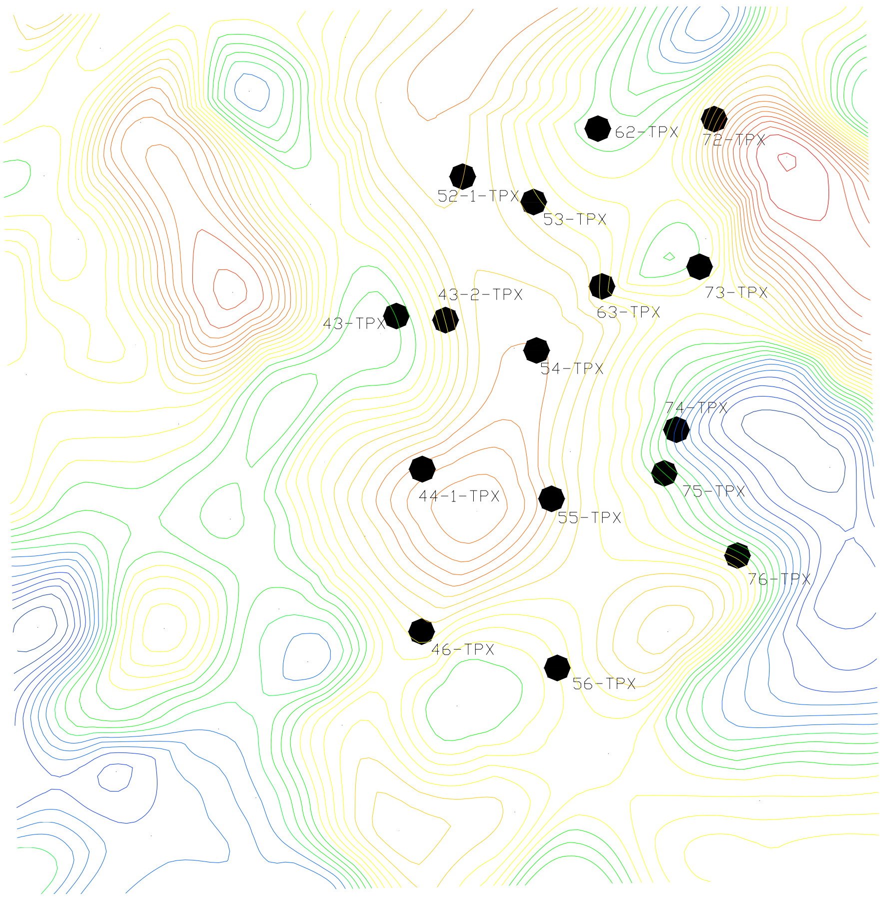


Figure 24 Tensleep Hydrocarbon Thickness with Section 10 Tensleep Wells

Conclusions

RMOTC was present during a live test of the airborne micro-gravity/electric field measuring system aboard a single engine aircraf, conducted by Electro-Seise, Inc. The aircraft was guided by a sophisticated DGPS system working in tandem with data logging equipment. The resultant data was accurate for ground positioning, elevation, speed of aircraft, and data sampling repeatability. Data collection was fast, environmental friendly, and non-intrusive.

Electro-Seise states that by using the two-line profile technique (Northerly and Southerly data point collection), “no correction is needed to manipulate the data, such as the Bouger Algorithms, for corrections in the vertical component of mass distortions.”

Structure maps, as presented by Electro-Seise, were found to overlay the known structure of Teapot Dome. Individual contour analysis identified the most useful individual levels. For example, the contour level of (-100) for the Second Wall Creek graphically gave a very good indication of the top of the Teapot Anticlinal Structure (Figure 18). At lower contour levels, a general northwest by southeast structure was indicated. The stand-alone capability of the Electro-Seise technology was validated based on the above correlation.

Fault maps, as presented by Electro-Seise, were consistent with the known fault strike at Teapot Dome. This alternate fault interpretation may indicate specific areas of focus for recent 3D Seismic data (January 2001).

The projected hydrocarbon thickness maps, as presented by Electro-Seise, correspond to some of the known reservoir production histories of the various formations at RMOTC. In other cases, the hydrocarbon thickness appeared to differ from known reservoir trends. Some individual wells with high cumulative oil production matched the high hydrocarbon thickness region. Conversely, several wells with lower cumulative oil production matched the lower hydrocarbon thickness regions. Exceptions to the correlations were also found to be true.

Gravity survey maps, such as residual and Bouger, have been used in the industry for many decades. Similarly, the Electro-Seise technology is believed to be useful in identifying gross structures, faulting directions, and possibly hydrocarbon potential.

Recent advances in technology and software development combined with accurate DGPS and portable computing power, such as the Electro-Seise technology, should make useful additions for frontier exploration and development programs.

References

[1.] Exploring for Oil and Gas Traps, Treatise of Petroleum Technology, Handbook of Petroleum Technology, Copyright 1999,Chapter 15, Section A, pages 15-1 through 15-14.

[2.] The SPE Image Library, Copyright 1995, Society of Petroleum Engineers, Inc.

[3.] The Oil and Gas Journal, February 26, 2001 issue, Page 17.